1889

Experiments with a lathe

Fritz August Weihe

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The disadvantages under which these experiments were undertaken were so numerous that the results obtained by them cannot be regarded as being correct and giving a true statement of the conditions of affairs. The engine driving the lathe was a common slide-valve throttling engine with a piston of four inches and a half diameter and a stroke equal to nine inches. The engine is very old, and bearings, cylinder and face and seat of the valve were very well worn out and especially the different bearings could not have been adjusted properly without everything being trued up which would have required too much time and labor. No self-lubricators were connected with the engine and this want was a source of great errors. The friction-diagrams differed widely according to the time which had passed after oiling. This was especially noticeable when the oiling of piston and slide-valve had been neglected for but a short time.

An other disadvantage was the fact that the shafting of the whole shop had to be driven at the same time, while making the experiments. This would otherwise have been favorable, acting similar to a fly-wheel and thus securing a more uniform motion, but in this case necessitated a longer waiting untill the speed had adjusted itself to the new conditions. But the piece worked upon was comparatively short and did not allow a long waiting if it was desired to take more than one set of indicator diagrams under the same conditions.

These unfavorable circumstances named above are sufficient to say that the results obtained are of no or but little practical value. The results will however be used, assuming them to be correct, and a trial will be made to show how they might have been of some interest and what conclusions might have been drawn from them.

The lathe employed in making these experiments was made by F. E. Reed, Worchester. Mass. The largest piece that could be worked upon could not be more than six inches in diameter and about four feet and a half long. J. W. Thompson's indicators were used to take the diagrams. The difference between the diagrams taken when working and the friction-diagrams gave the horsepower required to run the lathe and to do work upon the metal.

In the tables on the following page columns 2 to 4 give the following data:

1. Area of a set of indicator diagrams taken simultaneously at head and crank end.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	
1.	2.17	8.449	170	.619	.114	11.41	1.48	$\frac{1}{12}$	$\frac{1}{24}$	.1778	1.56	.1051	.917	29.70	.084
2.	2.87	11.164	165	.665	.164	22.72	″	″	″	.3541	2.15	.2141	1.30	62.16	.100
3.	3.25	12.643	166	.759	.154	22.84	″	″	″	.3572	2.32	.2152	1.40	62.28	.092
4.	3.53	13.731	165	.818	.213	36.15	″	″	″	.5676	2.66	.3440	1.61	98.40	.129
5.	3.02	11.748	168	.713	.108	10.00	2.13	″	″	.3630	3.361	.2161	2.00	39.00	.064
6.	2.97	11.512	166	.700	.095	15.03	″	″	″	.5461	5.74	.3289	3.46	59.35	.057
7.	3.16	11.294	168	.746	.101	23.16	″	″	″	.8410	8.32	.5013	4.95	90.31	.060
8.	3.67	14.266	167	.860	.255	36.50	″	″	″	1.3249	5.29	.7931	3.17	143.20	.152
9.	2.30	8.947	167	.640	.139	11.21	3.21	″	″	.3875	2.78	.2321	1.66	66.71	.083
10.	2.51	9.764	167	.689	.188	15.12	″	″	″	.5225	2.78	.3128	1.65	90.01	.112
11.	3.04	11.825	168	.718	.133	10.01	3.37	″	″	.3630	3.212	.2161	1.91	62.20	.080
12.	3.17	12.325	168	.748	.143	15.21	″	″	″	.5518	3.858	.328	2.29	94.54	.085
13.	3.45	13.421	162	.785	.180	22.34	″	″	″	.8095	4.491	.493	2.77	143.70	.111

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	
14.	3.92	15.249	165	.909	.304	36.15	3.37	$\frac{1}{12}$	$\frac{1}{24}$	1.043	3.76	.693	2.27	229.20	.184
15.	3.70	14.393	175	.910	.305	24.12	3.53	"	"	.9602	3.18	.548	1.80	157.71	.174
16.	4.07	15.832	180	1.029	.424	39.41	"	"	"	1.4972	3.53	.831	2.01	240.10	.235
17.	3.16	12.292	157	.697	.192	14.22	3.70	"	"	.5656	2.94	.360	1.87	103.81	.122
18.	3.56	13.848	170	.850	.245	23.43	"	"	"	.9316	3.84	.548	2.26	158.23	.145
19.	4.30	16.727	168	1.015	.410	36.81	"	"	"	1.4651	3.57	.872	2.12	257.31	.244
20.	2.91	11.320	168	.687	.182	10.01	3.86	"	"	.4161	2.28	.247	1.35	74.91	.108
21.	2.90	11.289	168	.685	.180	10.01	"	"	"	.4161	2.31	.247	1.36	74.91	.107
22.	2.99	11.631	158	.664	.159	9.31	"	"	"	.3873	2.43	.245	1.53	70.60	.100
23.	3.02	11.748	158	.672	.168	9.31	"	"	"	.3873	2.30	.245	1.45	70.60	.106
24.	2.23	8.675	170	.633	.132	11.41	3.21	$\frac{1}{6}$	$\frac{1}{24}$	.6991	5.20	.411	3.11	60.01	.077
25.	2.71	10.542	171	.651	.150	15.42	"	"	"	.950	6.33	.551	3.72	89.13	.087
26.	3.08	11.981	163	.705	.204	22.46	"	"	"	1.379	6.76	.846	4.14	135.21	.119

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	
27.	3.41	13.265	162	.776	.275	35.72	3.21	$\frac{1}{6}$	$\frac{1}{24}$	2.188	7.91	1.350	4.82	216.01	.169
28.	3.35	12.932	160	.747	.142	9.44	3.37	$\frac{1}{6}$	"	.709	5.01	.443	3.12	60.9	.088
29.	4.02	15.638	153	.865	.260	13.81	"	"	"	1.037	4.13	.667	2.61	93.12	.170
30.	3.35	13.032	163	.768	.163	9.60	4.02	"	"	.8236	5.05	.504	3.06	72.91	.100
31.	3.48	13.537	145	.709	.104	8.54	4.187	$\frac{1}{4}$	"	1.135	10.91	.782	7.05	76.81	.071
32.	2.95	11.476	175	.725	.120	38.34	4.02	$\frac{1}{12}$	$\frac{1}{52}$	.912	7.62	.520	4.91	273.40	.068
33.	2.99	11.631	183	.769	.164	40.01	4.187	"	"	.968	5.90	.531	3.22	283.51	.090
34	2.93	11.601	185	.767	.162	40.80	"	"	"	1.050	6.01	.567	3.24	285.53	.083

2. Mean effective pressure,
3. Number of revolutions which the engine makes per minute.
Knowing the diameter of piston and its stroke we get the data in column 5, i.e. the horse-power required to run shafting and lathe. Subtracting from this the average horse-power obtained from a number of friction diagrams we get the data in column 7, which give the horse-power necessary to run the lathe and to do the work. Columns 8, 9 and 10 give diameter of working piece, the depth of the cut and the feed in inches respectively. In column 11 is given in cubic inches the metal removed per minute, 12 gives the metal removed per horse-power per minute and in 13 and 14 the same data respectively are calculated for 100 revolutions per minute. In the last column is given the circumferencial velocity in inches per minute, the engine

supposed to make 100 R.p.M. The diameter used in these calculations is the mean between the diameters before and after cutting respectively.

Columns 14 and 15 are evidently the most interesting and most valuable ones. In a large machine shop where one engine drives a great number of different tools a certain part of the horse-power developed by this engine is allowed for each separate tool and this available power should of course be used to greatest advantage. The machinist has it in his hand to work his tool in different ways accomplishing in either way the same result in the same time.

The depth of the cut is generally more or less fixed if not more than one cut with each tool is to be taken, but a choice exists as to speed and feed, and only results obtained from experiments can show whether it is more economical to feed fast and turn slowly or whether this is the case by feeding slowly and turning fast.

The want of a definite laying out of the work before these experiments were undertaken are the reason why they cannot be used to show whether higher circumferencial velocity or faster feed is to be preferred. It seems as if the latter i.e. a faster feed should be more economical as the tool has to cut less metal while all other things remain the same. Only the work of friction will be increased because the pressure at the circumference of the work becomes greater and therefore the pressure in the different bearings.

The only way in which to make use of the results obtained from the experiments, is to see under which working conditions the most metal has been removed with one horse-power. From the data in number 1 to 4 we see that the highest speed has given the highest result. From 5 to 8 the second highest speed gives the best result. The same is true from 11 to 14 and from 17 to 19. In the other instances with the exception of 20 to 23 and of 28 to 29 the higher the speed the higher the result.

To see whether in having a small or a large diameter a better use is made of the available power we may compare number 1 and the average result obtained from 20 to 23. In 1 with a diameter of 1.48 inches one horse-power removes but 0.917 cubic inches while it removes about 3.3 cubic inches with a diameter equal to 3.86 inches, which shows that there is less loss in large work than in small. This agrees evidently with theory. In order to remove a certain amount of metal from a piece of small diameter is has to make a greater number of revolutions. The pressure at the end of the tool is in both cases the same and may even be larger in small work for the chips are bent to a smaller spiral. The friction will therefore be the same in each revolution and the whole amount of friction will be larger in small than in large work.

The best use of the available power has been made in number 31 with a diameter of 4.187 inches the depth of the cut being $\frac{1}{4}$ inch and the feed $\frac{1}{24}$ inch, and from 25 to 29 it can be seen that a deeper cut is more economical.

Having the same depth of cut and the same feed the pressure at the circumference of the work will practically be the same for different diameters. The work of friction will therefore be about constant. But the whole amount of work will be directly proportional to the diameter of the piece worked upon. Of the results from the experiments were perfectly correct it would be easy to find the work of friction in the following way. Using a sytem of co-ordinates and laying off the diameter of the piece on the axis of x and making the amount of work equal to y we would get a number of points which, when joined should nearly lie in a straight line. This line prolonged until it intersects the axis of y would give in this intercept the work of friction. By making $x=0$ we would get a value for y which is not equal to the whole work of friction for no pressure exists at the end of the tool which causes friction in feeding screws and some of the other journals.

A trial which was made to find in this way the work of friction failed because the experiments were not numerous enough.